The Impact of Smartphone Usage on Cognitive and Psychomotor Performance Among Medical Students: A Cross-Sectional Study

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Abstract:

In today's world, smart phones have become an integral part of everyday life, connecting users to the outside world constantly. This widespread use of smart phones significantly increases exposure to LED light emitted from screens for prolonged periods. Long-term exposure to smartphone light has been associated with adverse effects on physical and mental health, particularly among college students, posing a public health concern. Research indicates that extended screen time may contribute to mental and visual fatigue, potentially leading to sleep disorders, mood swings, insomnia, dry eyes, computer vision syndrome, and in more severe cases, tactile hallucinations and delusions. Given these risks, it is crucial to investigate how smartphone usage may affect cognitive functions, particularly reaction times. **Aim**: This study aims to evaluate the visual reaction time (VRT) and auditory reaction time (ART) among medical students who are regular smartphone users. **Materials and Methods**: A cross-sectional study was conducted to assess VRT and ART among medical students aged 18–25 years at SRM Medical College & Hospital, Kattankulathur. The participants' reaction time was measured both before and after smartphone usage using a Chronoscope – Digital to evaluate cognition. Specifically, two auditory and three visual reaction time tests were administered. Prior informed consent was obtained from all participants before conducting the tests. **Results**: The results demonstrated a significant increase in both auditory and visual reaction time after a period of smartphone usage. ART and VRT were notably prolonged, highlighting potential cognitive decline with continuous smartphone use. This finding suggests that excessive screen time may have long-term implications on cognitive health, particularly concerning reaction time and mental sharpness. **Conclusion**: The findings of this study underscore the potential cognitive risks associated with prolonged smartphone usage. Extended screen time was shown to prolong visual and auditory reaction times, indicating a decline in cognitive function among the participants. Medical students, and by extension, the general population, should be made aware of the detrimental effects of excessive screen exposure. Limiting screen time is essential to prevent future cognitive risks and maintain mental well-being.

Keywords: Smartphone usage, visual reaction time, auditory reaction time, medical students, cognitive function.

Introduction:

The increasing prevalence of smartphone usage among medical students raises important questions regarding its impact on cognitive functions, particularly reaction times. Reaction time (RT), defined as the duration between the presentation of a sensory stimulus and the corresponding behavioral response, serves as a crucial indicator of an individual's alertness and the efficiency of their central nervous system in processing sensory information and executing motor responses [1], [2]. Reaction time, typically measured in milliseconds, represents the speed of neurophysiological, cognitive, and information processing in response to a stimulus. It involves a sequence of events starting with the reception of sensory input (either visual or auditory), followed by information processing, decision-making, and culminating in the execution of a motor response. These steps occur consecutively, contributing to the overall reaction time [2], [3], [4]. According to the Telecom Regulatory Authority of India (TRAI), there were 1.166 billion active internet users in India in 2022 [5]. Recent global surveys have revealed that nearly 70% of internet users, particularly the younger population, have increasingly relied on smartphones. The COVID-19 pandemic, which emerged as a major global health and economic crisis, disrupted daily life significantly [6]. This shift in smartphone usage was further amplified by extended lockdowns during the pandemic, which resulted in increased digital engagement and widespread mobile device use globally [7]. The widespread use of smartphones during the pandemic increased screen time significantly, leading to concerns about potential negative health effects. Excessive smartphone use has been linked to increased stress, depression, anxiety, sleep disorders, restlessness, and fatigue, all of which can contribute to cognitive impairment [5], [8]. Measuring RT has been a valuable tool for understanding cognitive information processing. RT is a measure of neural processing speed, expressed in milliseconds. It can be influenced by various factors, including age, gender, handedness, vision, practice, fatigue, fasting, neural conduction distance, intelligence, and the type of stimulus. The concept of RT was first described by Abu Rayhan al-Biruni. Franciscus Cornelis Donders pioneered systematic measurements of human RT using a telegraph-like device in the 1860s. Before Donders' work, there was little to no research on measuring human RT [9]. Studies have classified reaction times into three main types: Simple Reaction Time (SRT), characterized by a single stimulus prompting a single response; Recognition Reaction Time (RRT), which requires individuals to respond to specific stimuli while disregarding others; and Choice Reaction Time (CRT), where multiple stimuli are paired with multiple responses [10]. Additionally, reaction time measurement can be categorized based on the type of stimulus, with Visual Reaction Time (VRT) pertaining to visual stimuli and Auditory Reaction Time (ART) associated with auditory stimuli [9].Understanding these distinctions is crucial for interpreting the effects of different stimuli on reaction time in the context of our study.

In modern society, excessive use of electronic devices, such as smartphones, can negatively influence our psychomotor skills, sensory perception, and cognitive functions [11]. While numerous studies have investigated the cognitive effects of computer use on reaction times, there remains a notable gap in research specifically focusing on the implications of smartphone usage on ART and VRT among younger populations, including medical students.

Understanding how prolonged exposure to screens affects these reaction times is critical, as they reflect broader cognitive impacts associated with smartphone use [12].

This study aims to evaluate the association between smartphone use and visual as well as auditory reaction times in medical students, utilizing a cross-sectional study design. The assessment of these parameters is expected to provide critical insights into the effects of modern technology on cognitive function within this specific population.

Objective

This study aimed to assess cognitive function by measuring VRT and ART among medical students using smartphones.

Methodology

A cross-sectional study was conducted among medical students at SRM Medical College Hospital & Research Centre, aged 18–25 years, with the purpose of comparing reaction times before and after mobile phone usage. Cognitive function was evaluated by Chronoscope - Digital (2 Auditory & 3 Visual R.T) measuring VRT and ART using the following procedures.

VRT was measured by instructing the subject to press the stop button with their right index finger as soon as a red light appears followed by yellow and then green light which was initiated by the examiner. The reaction time was recorded and analyzed. For ART, the examiner initiated the Buzzer I and then Buzzer II and the subject was instructed to press the stop button as soon as they heard the tone. This reaction time was also recorded and analyzed. All tests were conducted after obtaining informed consent from the participants, and institutional ethical clearance was secured before the study commenced. The study involved 182 medical students aged 18–25 years from SRM Medical College Hospital & Research Centre. Participants with corrected visual acuity (with spectacles) were included, while those with a history of retinal diseases, neurological disorders, or brain injuries were excluded.

After one hour of mobile phone usage, both VRT and ART were measured again. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 21. Paired Student’s t-tests were applied to compare VRT and ART before and after mobile usage. Results indicated that both VRT and ART were prolonged following mobile phone usage compared to measurements taken before usage.

Result

The mean VRT (Figure 1) was analyzed across three different color stimuli: red, green, and yellow, in a sample of 182 participants. The mean VRTs for the three colors were relatively similar, ranging from 0.005 to 0.017 (Table 1), indicating only slight variations in response times across the stimuli. Standard deviation (SD) values for each condition were comparable, reflecting consistent variability in the reaction times.

A significant difference in VRT was observed for the red, yellow, green stimulus, before usage of mobile and after an hour of mobile usage with a p-value of 0.000*** (Table 1), a statistically significant difference indicating an increased reaction time after usage of phone.

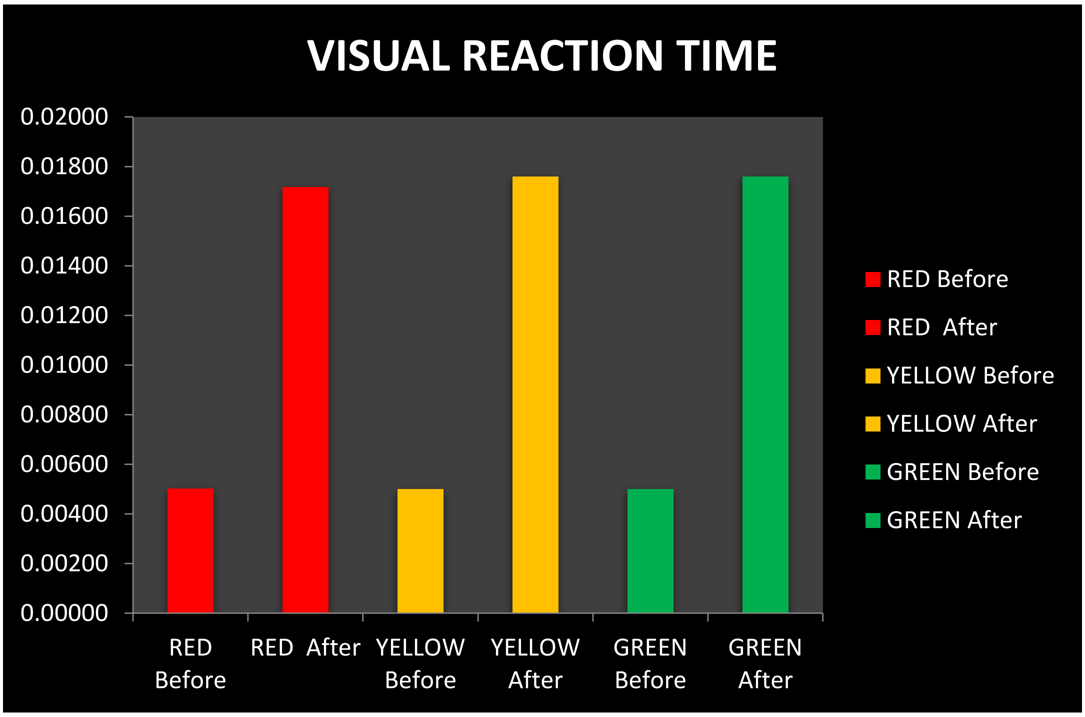
Table-1: Effect of visual reaction time value before and after use of smartphone

VRT		Mean ± SD	N	P value
RED	Before	0.00502+0.00155	182	0.000***
	After	0.01718+0.00353		
YELLOW	Before	0.00544+0.00174		
	After	0.01761+0.00344		
GREEN	Before	0.00541+0.00194		
	After	0.01769+0.00345		

VRT: Visual reaction time, SD: Standard deviation, p =0.000***-highly significant

The VRT in the graph shows red before, yellow before, and green before representing measurements taken before mobile phone usage, while red after, yellow after, and green after reflect the measurements taken after one hour of mobile phone usage. Despite the significant difference observed, the overall variation in mean VRTs between the three groups before and after the phone usage showing a prolonged reaction time indicating a cognitive delay.

Figure-1: Graphical representation of visual reaction time before and after use of smartphone



The mean ART (Figure 2) was analyzed for two auditory stimuli, BUZZER I and BUZZER II before and after mobile usage for an hour. Notably, the mean ART for BUZZER I is slightly lower than that for BUZZER II. The comparable standard deviation (SD) values for both conditions indicate a consistent level of variability across the data.

Statistical analysis reveals a significant difference between the mean ARTs for BUZZER I before, after and BUZZER II before, after mobile usage, with a highly signicant p-value of 0.000*** (Table 2). This finding highlights the statistical significance of the observed differences, indicating that participants exhibited quicker reaction times when responding to BUZZER I compared to BUZZER II.

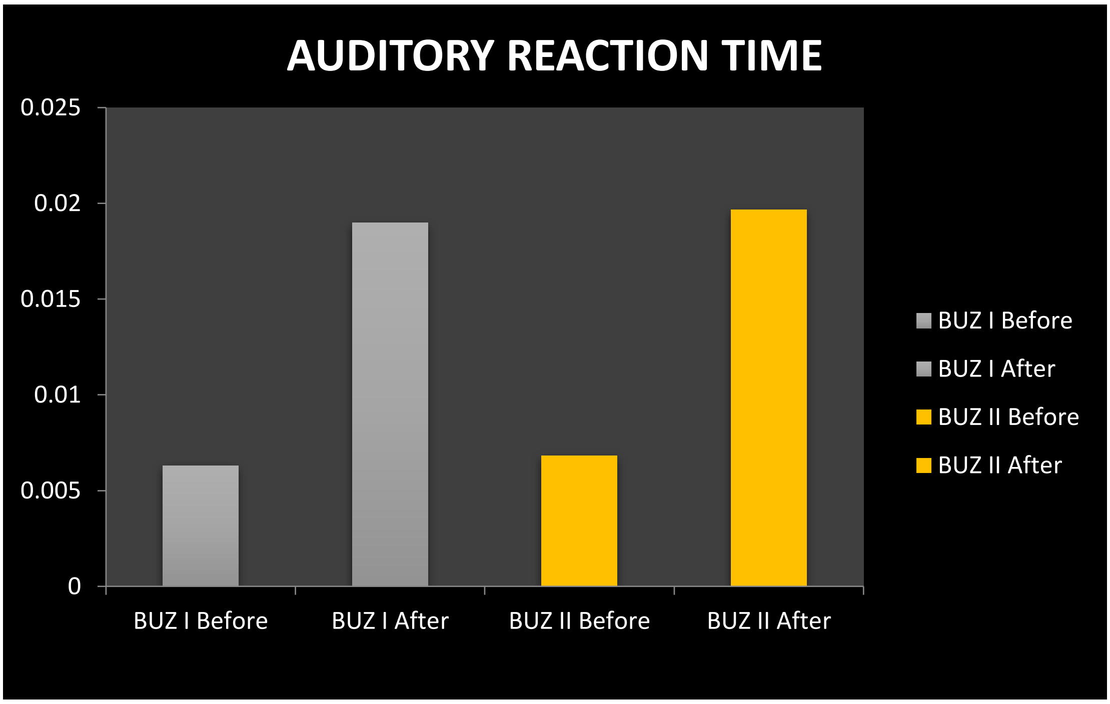
Table-2: Effect of auditory reaction time value before and after use of smartphone

ART		Mean + SD	N	P value
BUZZER I	Before	0.00629+0.00211	182	0.000***
	After	0.01900+0.00365		
BUZZER II	Before	0.00683+0.00231		
	After	0.01966+0.00400		

ART: Auditory reaction time, SD: Standard deviation, p =0.000***highly significant

In the graph, BUZZER I before and BUZZER I after represent the reaction times measured before usage of mobile phone and after one hour of mobile phone usage, while BUZZER II before and BUZZER II after correspond to the same timing for the second auditory stimulus. Overall, the findings imply that response time were greatly impacted by the auditory stimuli after an hour of phone usage indicating a decline in cognition.

Figure-2: Graphical representation of auditory reaction time before and after use of Smartphone



Discussion

This study examined the effects of smartphone usage on visual and auditory reaction time among medical students, revealing significant differences in response time across various stimuli.

The analysis of mean VRT for three color stimuli—red, green, and yellow—yielded important findings. In a sample of 182 participants, the mean VRTs for these stimuli were relatively consistent, ranging from 0.005 to 0.017 (Table 1), which indicates minimal variability in response time. The comparable standard deviation (SD) values across color conditions suggest a stable level of variability in the reaction time.

A statistically significant difference was observed for the red, yellow,green stimulus, before and after an hour of mobile phone usage with a p-value of 0.000*** (Table 1). The graphical representation of VRT (Figure 1) displays measurements collected before and after mobile phone usage; specifically, "red before," "yellow before," and "green before" represent VRTs prior to mobile usage, while "red after," "yellow after," and "green after" indicate VRTs measured after one hour of mobile phone usage.

Importantly, both the VRT and ART for BUZZER I and BUZZER II were prolonged following one hour of mobile phone usage compared to baseline measurements. This pattern suggests that the cognitive load associated with smartphone use may negatively impact reaction times for both visual and auditory stimuli.

Further analysis of mean ART for BUZZER I and BUZZER II showed that the mean ART for BUZZER I was slightly lower than for BUZZER II, indicating faster responses to the first auditory stimulus. The consistent SD values across both conditions reflect uniform variability in the dataset.

Statistical analysis further revealed a significant difference between the mean ARTs for BUZZER I and BUZZER II, with a p-value of 0.000*** (Table 2). This underscores the statistical significance of the observed differences, demonstrating that participants had quicker reaction times in response to BUZZER I compared to BUZZER II. The graphical representation of ART (Figure 2), with "BUZZER I before" and "BUZZER I after" reflecting reaction time measured prior to and after mobile phone usage, supports this trend for BUZZER II as well.

These findings indicate that both visual and auditory stimuli significantly influence reaction times, with color and type of auditory stimulus being critical factors in response efficiency. Additionally, the prolonged reaction times observed following one hour of mobile phone usage suggest that engagement with mobile devices may impair cognitive processing speed. These findings were analysed by the statistical version(SPSS)21 [13,14].

The implications of these results are particularly relevant for medical training, highlighting the importance of optimizing auditory alerts and notifications to enhance responsiveness in critical situations. Furthermore, the blue light emitted by smartphone screens has been shown to disrupt melatonin production, which regulates sleep-wake cycles[15,16]. Such disruptions can lead to cognitive impairments, including slower reaction times. Prolonged exposure to blue light may also result in eye strain and fatigue, further impacting cognitive performance [17], [18], [19].

Research indicates that auditory stimuli reach the brain in approximately 8 to 10 milliseconds, while visual stimuli take between 20 and 40 milliseconds. This suggests that ART are generally faster than VRT as auditory information reaches the cortex more quickly than visual information [20]. Additionally, findings suggest that simple reaction times are faster for auditory stimuli than for visual ones, with auditory stimuli demonstrating rapid conduction to the motor cortex and swift processing in the auditory cortex [21]. Although some studies have reported faster reaction time for visual stimuli under certain conditions, our research supports the notion that ART are quicker than VRT, even among medical students, when controlling for potential confounding factors [22].

The findings of this study highlight the potential negative consequences of excessive smartphone use on cognitive function. Medical students, who are often heavy smartphone users, should be made aware of these risks and encouraged to adopt healthier screen time habits. Limiting smartphone use, especially before sleep, and using blue light filters can help mitigate the potential negative effects on cognitive performance.

Research indicates that smartphone usage significantly impacts reaction time, particularly among younger individuals. Studies have shown that frequent engagement with smartphones leads to greater distraction, which in turn prolongs both visual and auditory reaction time. Excessive smartphone use has been associated with reduced attention to tasks at hand, resulting in slower psychomotor responses to stimuli [23]. The findings of this study are consistent with existing literature that emphasizes the link between cognitive and psychomotor functions and reaction time. Student success in the learning process relies on key factors such as attention, concentration, arousal level, and processing speed, all of which influence response time to various stimuli. Studies indicate a significant relationship between response time and learning, showing that faster response time align with quicker learning speeds [24]. Moreover, the ability to rapidly process information and respond is critical for optimal performance, especially in high-pressure environments like medical settings. However, excessive smartphone use has been linked to reduced sleep duration and increased nocturnal awakenings, which can impair cognitive functions, including attention and reaction time, thereby affecting learning and performance outcomes [25], [26]. Frequent use of smartphones, particularly before bedtime, has been shown to negatively impact sleep-wake patterns due to exposure to bright screens, which inhibits melatonin secretion and disrupts the sleep cycle[27], [28]. These disturbances in sleep have been linked to slower reaction times and decreased alertness during the day, as attention deficits often arise from poor sleep quality [29]. Additionally, the type of content consumed, such as stimulating or violent media, further exacerbates sleep disturbances and cognitive impairment [30]. Given that both visual and auditory reaction times are influenced by cognitive function, it is likely that the negative effects of smartphone overuse can extend to reaction time tasks in medical students, who rely heavily on these functions for their academic and clinical duties.

Overall, this study highlights the necessity of understanding sensory processing in the context of smartphone usage, particularly as technology continues to be integrated into educational frameworks. Future research should explore the broader implications of these findings on learning outcomes and clinical performance among medical students.

Limitations and Future Directions:

This study has several limitations that should be acknowledged. First, the cross-sectional design restricts our ability to establish causality between smartphone usage and cognitive function. Longitudinal studies are needed to determine whether a cause-and-effect relationship exists. Additionally, our sample was limited to medical students, which may reduce the generalizability of the findings to other populations. Future research should aim to include a more diverse demographic to ensure broader applicability of the results.

Furthermore, this study did not account for the specific types of smartphone activities (e.g., social media, gaming), which may have varying impacts on cognitive performance. Investigating the effects of specific smartphone functions in future studies could provide deeper insights into how different activities influence cognitive and psychomotor skills. It is also important to assess the long-term cognitive effects of smartphone use, particularly in younger populations who may be more susceptible to its influence.

Another limitation is the uncertainty surrounding participants' adherence to the instruction to abstain from smartphone usage one day prior to the experiment. While this was requested, we could not verify whether it was followed, potentially introducing bias into the results. Future studies should adopt more robust methods to monitor compliance and reduce the likelihood of this issue affecting the data.

Conclusion

This study demonstrates a significant association between excessive smartphone usage and prolonged visual and auditory reaction times among medical students. The findings suggest that smartphone overuse, potentially compounded by its negative impact on sleep quality, can impair cognitive function and delay reaction time. Given the critical role of quick and accurate responses in both academic and clinical settings, these results highlight the need for increased awareness and strategies to promote balanced smartphone usage. Further research is recommended to explore interventions that could mitigate these effects and improve overall cognitive performance in medical students.

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